APPENDIX A – Sediment Compatibility Analysis Report

I. SEDIMENT ANALYSIS

A. EAST OCEAN VIEW BEACH SEDIMENT ANALYSIS

Sediment samples were collected along the East Ocean View Beach project area at every fifth survey transect (~500 ft) used for the beach surveys, beginning with the transect closest to the Little Creek Inlet Jetty (See **Figure 1-1**). There were a total of 11 transects at which sediment samples were collected. For each of these transects, sand samples were collected at 1) top of dune, 2) toe of dune, 3) mid-beach (halfway between toe of dune and water line), 4) high water line, and 5) elevation = -6' NAVD 88, and 6) elevation = -15' NAVD 88. A standard sieve analysis (following ASTM C136 standards) was performed for each sample using the following sieve sizes: #4, #10, #16, #30, #40, #50, #60, #80, #100, #140, and #200.

1. *Grain Size Distributions*

Based on methodologies presented in the U.S. Army Corps of Engineers (USACOE) Coastal Engineering Manual (CEM), a composite native beach grain size distribution was computed from the available sediment data. Sediment data (grain size distributions) were averaged alongshore for all 11 sample locations at 1) dune toe, 2) mid beach, and 3)-6 ft. Next, an overall average distribution was computed from the average dune toe, mid beach, and -6 ft distributions, yielding the composite grain size distribution for the project area. **Figure 1-2** shows the average distributions computed for the dune toe, mid beach, and -6 ft samples, and the resulting composite distribution.

2. *Median Grain Size*

Median grain sizes were computed for each station and sample location and averaged along each transect (between the dune toe and -6 ft) and along the shoreline. As shown in **Table 1-1**, the median grain sizes generally increased in moving from east to west along the project area.

Table 1-1 Median Grain Sizes for East Ocean View Beach Sediment Samples

Station	d50 – dune toe (mm)	d50 – mid beach (mm)	d50 - -6 ft (mm)	d50 - avg of dune toe, mid beach, -6 ft (mm)
1+00	NA	NA	0.16	0.16
6+00	NA	NA	0.14	0.14
11+00	0.22	0.23	0.14	0.20
16+00	0.23	0.19	0.13	0.18
21+00	0.23	0.19	0.30	0.24
26+00	0.26	0.25	0.17	0.23
31+00	0.23	0.25	0.29	0.26
36+00	0.23	0.23	0.19	0.22
41+00	0.25	0.32	0.18	0.25
46+00	0.34	0.35	0.33	0.34
51+00	0.32	0.32	0.21	0.28
AVG	**0.26**	**0.26**	**0.20**	[redacted]
MIN	**0.22**	**0.19**	**0.13**	[redacted]
MAX	**0.34**	**0.35**	**0.33**	[redacted]

3. *Characteristics for Calculation of Overfill Factor*

The CEM defines the overfill factor (R_A) as "*the volume of borrow material required to produce a stable unit of usable fill material with the same grain size characteristics as the native beach sand.*" The closer the overfill ratio is to 1.0, the better the sand source. The methodology for computing the overfill factor was taken from the CEM and consists of calculating relationships between the means and standard deviations of the phi-scale grain size distirbutionsbetween the potential borrow site and the native beach. These relationships can then be plotted on a nomograph in the CEM to determine the overfill factor, R_A.

Characteristics of the native beach sand were determined from the composite grain size distribution (avg of distributions between dune toe and -6 ft for entire study area). While there is some variability in these distributions along shore, an overall average was used since it was fairly certain that the borrow site and construction scheduling and costs would not allow specialized dredging and placement programs. The required input for computing the overfill factors were determined from the phi-scale grain size distribution. The phi scale distribution for the native beach and the resulting characteristics used for computing the overfill factor for the native beach are shown on **Figure 1-3**.

Based on an extensive review of literature related to sand resources in the lower Chesapeake Bay and the Virginia Inner-Continental Shelf, the following areas were selected for further investigation as potential borrow sources for East Ocean View beach nourishment.

- Thimble Shoal Channel – site of USACOE's dredging project,
- Sandbridge Shoal – located within the Southern Inner-Continental Shelf, offshore of Sandbridge Beach and South of Virginia Beach.

B. THIMBLE SHOAL CHANNEL SEDIMENT ANALYSIS

Three data sources were available for analyzing the compatibility of the Thimble Shoal Channel dredge material with the native beach. These sources were:

- Virginia Institute of Marine Science (VIMS) study (Hobbs et al, 1982) of sand resources in the lower Chesapeake Bay and their suitability as beach fill for several nearby sites, including Norfolk Beaches. This study included boring data and grain size distributions for 6 borings taken near or in the potential dredge area for the USACOE project.

- Waterway Surveys & Engineering Ltd ("Waterway") report entitled "Preliminary Design for Disposal of Dredged Material from Thimble Shoal Channel on West Ocean View Beaches, Norfolk, Virginia" (June 1984). This study included an investigation of sand resources in and near the Thimble Shoal Channel. Two composite grain size distributions were presented for portions of the channel containing potential beach fill material, and overlapping the proposed extent of the USACOE dredging in Thimble Shoal Channel. The composite grain size distributions were developed from individual borings taken in the channel for this and previous studies. Unfortunately, the grain size distributions for these individual borings were not presented within the report.

- USACOE plans and specs for Thimble Shoal Channel dredging, including borings near the proposed dredging project area. The borings are dated 1984-1985 and include general characteristics such as median grain size (d50), percentage of fines, description of material, and evaluation of material (good or bad for beach fill). Unfortunately, detailed grain size distributions were not available for these borings.

Figure 1-4 shows the location of the VIMS, Waterway, and USACOE borings. The USACOE borings are contained mainly in and adjacent to the channel while most of the VIMS borings are located on the banks surrounding the channel. As stated, the Waterway borings are composite distributions developed from borings taken over two areas within the channel ("Sediment Y" and "Sediment Z"). It should be noted that all of this boring data was collected in the early 1980's, and thereby subject to have changed. For the remainder of this report, all elevations reported for the offshore region and in reference to Thimble Shoal Channel are in feet below Mean Lower Low Water (MLLW), based on the National Ocean Service (NOS) tidal benchmark at the Chesapeake Bay Bridge Tunnel.

1. Summary of Thimble Shoal Boring Analysis (VIMS Data)

Grain size distributions were available for each of the six borings shown on **Figure 1-4**, at numerous sample depths. Given that the Congressionally Authorized depth for Thimble Shoal Channel is -58 ft, for each of the six borings, a grain size distribution which was within the potential dredging depth range(not shallower than -44 ft and not deeper than -58 ft) was selected and plotted against the composite native beach grain size distribution. The samples for boring

WB093 were significantly shallower than the potential dredging depths within the channel, and were therefore excluded from this analysis. **Figure 1-5** shows the 5 selected VIMS boring distributions against the native beach composite distribution.

Of the 5 distributions shown on **Figure 1-5**, two distributions, WB097 and WB096, were selected for a more detailed comparison to the native beach. Boring WB097 was the only boring located within the dredging project extent (see **Figure 1-4**), and had a distribution at the selected sample depth which was similar in shape to the native beach distribution. All of the other borings were located outside of the Thimble Shoal Channel boundaries. Of these, boring WB096 was selected because its distribution was similar in shape to the native beach, and the corresponding depth of the sample was close to the potential dredging depth for the channel. Borings WB092 and WB094 were not selected because both distributions were significantly coarser overall than the native beach distribution and were taken at sample depths which were shallower than the potential dredging depth in the channel. Finally, boring WB095 had a poorly graded distribution, with a significant percentage of both coarse material and fines and representing only one foot of material.

Boring WB097 consisted of two sample depths which were within the potential dredging range: 1)-50 to -55 ft and 2)-55 to -60 ft. Both of these grain size distributions were plotted against the composite native beach grain size distribution (See **Figure 1-6**). As shown on the figure, the grain size distribution from -50 to -55 ft is generally less coarse than the distribution for -55 to-60 ft. In addition, the size of the fines present in the -50 to -55 ft depth range matches well with that indicated on the native beach distribution.

Boring WB096 included three sample depths which were within the potential dredging range: 1)-44 to -49 ft, 2)-49 to -54 ft, and 3)-54 to -60 ft. As done for boring WB097, each of these grain size distributions were plotted against the composite native beach distribution (see **Figure 1-7**). While these distributions are quite similar, the grain size distribution from -49 to -54 ft is closest in shape to the native beach composite and is the most well-graded of the samples taken.

As part of the VIMS 1982 study, the overfill factors were computed for all borings (at numerous depths) against the native beach sand for a composite "Norfolk Beach" (i.e. complete 7 mile extent). To validate the use of the data, overfill factors were calculated for the VIMS borings WB097 and WB096 against the native beach material using the available data collected in this study. As was done for the native beach sediment, the grain size distributions were plotted on a phi scale, and the required characteristics were estimated from the curves. **Figures 1-8 and 1-9** show the phi-scale distributions for both WB097 and WB096 from which the characteristics used in computing the overfill factor were obtained. The overfill factors were computed using ACES (Automated Coastal Engineering System) software. For computing these factors, ACES requires the user to input the mean sediment diameters (M_φ) and the standard deviations (σ_φ) for the native and borrow materials. The following equations from the CEM were used for computing these parameters:

$$M_\varphi = \left(\frac{\varphi_{16} + \varphi_{50} + \varphi_{84}}{3}\right)$$

$$\sigma_\varphi = \left[\left(\frac{\varphi_{84} - \varphi_{16}}{4}\right) + \left(\frac{\varphi_{95} - \varphi_{5}}{6}\right)\right]$$

To correlate with the VIMS study, the overfill factors (R_A) were computed for the sample depths within the potential dredging depth range for both borings WB097 and WB096. The results of this analysis including the corresponding overfill factors presented in the VIMS report, are presented in **Table 1-2**. As one can see from the table, the calculated overfill factors are very close to those reported in the VIMS report. This further validates the use of this data set for evaluating material compatibility as beach fill on East Ocean View Beach.

Table 1-2 Overfill Factors Based on VIMS Borings WB097 and WB096

		NATIVE BEACH		BORROW SOURCE			VIMS
Boring	**Depth of Sample**	**$M_{\varphi n}$**	**$\sigma_{\varphi n}$**	**$M_{\varphi b}$**	**$\sigma_{\varphi b}$**	**R_A**	**R_A**
WB097	-50 to -55 ft	2.10	0.73	1.43	1.43	1.12	1.10
	-55 to -60 ft	2.10	0.73	1.07	1.07	1.00	1.00
WB096	-44 to -49	2.10	0.73	1.50	0.88	1.00	1.00
	-49 to -54	2.10	0.73	1.50	1.12	1.04	1.03
	-54 to -60	2.10	0.73	1.52	0.96	1.01	1.00

2. *Summary of Thimble Shoal Channel Boring Analysis (Waterway Data)*

The Waterway report data included composite grain size distributions for two locations within Thimble Shoal Channel. Both composite grain size distributions were developed from individual sediment borings ranging from the natural ground surface to approximately -55 ft within Thimble Shoal Channel. In addition to these distributions, the report contained a map which summarized the material present at each boring, characterizing it as clay, gravel, silt, sand, or some combination of these materials.

Sediment Y refers to a composite area extending along the southern lane of the channel (500 ft width) approximately 5000 ft west and 9000 ft east of the Chesapeake Bay Bridge Tunnel Crossing (see **Figure 1-4**). The report states that this composite distribution was based on three adjacent borings, with the results of the compatibility analyses indicating that this was suitable material for beach fill use on West Ocean View beach. Sediment Z refers to an area which encompasses the entire channel width (1000 ft) and extends from the east end of the Sediment Y area approximately 2 miles eastward. The report noted that the area defined as Sediment Z was concluded, in a previous study, to contain material which was suitable for beach fill on Fort Story beaches.

Figure 1-10 shows the composite grain size distributions for Sediment Y and Sediment Z plotted against the native beach composite distribution. As shown, both distributions are coarser overall and contain higher percentages of fines than the native beach distribution. As stated, the distribution for Sediment Y is a composite of three adjacent boring distributions, which are spread along the 14,000 ft length of the area. Given the large spacing between these borings, it is difficult to assess how representative this composite is of material present within this general area. Furthermore, on the map depicting the general material present at each boring, the borings used for this composite are identified as sand, while those within proximity to the north and west contain more fine material. Similarly, it is not clearly stated how many borings were used to develop the composite distribution for Sediment Z. Therefore, the distribution for Sediment Z may not account for local variations in the material.

To assess the suitability of these generalized borrow sources, the overfill factors were computed against the native beach composite distribution. **Figure 1-11** shows the phi-scale grain size distributions from which the characteristics required for calculating the overfill factor were obtained. **Table 1-3** shows the computed overfill factors.

Table 1-3 Overfill Factors Based on Waterway Grain Size Distributions

		NATIVE BEACH		BORROW SOURCE		
Sediment Area	**Depth of Sample**	$M_{\varphi n}$	$\sigma_{\varphi n}$	$M_{\varphi b}$	$\sigma_{\varphi b}$	R_A
Y	NG to -55 ft	2.10	0.73	1.57	0.98	1.01
Z	NG to -55 ft	2.10	0.73	2.03	1.06	1.16

3. *Summary of Thimble Shoal Channel Boring Analysis (USACOE Data)*

The information on sediment borings available from the USACOE plans and specifications for the dredging of Thimble Shoal Channel was used to develop a summary of the available borrow material by station along the project area. This summary allowed for narrowing down the potential borrow areas and focusing on specific locations at which to evaluate sediment compatibility. A summary of the sediment near and within the project site by station is presented below on **Table 1-4**, with average d50s and percentage of fines (corresponding to the percentage passing the 0.075 mm or the percentage retained for the 3.74 phi-size particle), where available. Note that the project stationing on the dredging plans began at Station 734+00, on the west end of the channel and extended to Station 1328+00 on the east end of the channel.

Table 1-4 Summary of USACOE Sediment Data by Station

Station Range	Description of Material (Avg d50, % fines where computed)
St 734+00 - 1090+00	▪ Material not compatible based on boring logs.- high percentage of fines
St 1090+70.17	▪ Chesapeake Bay Bridge Tunnel Crossing
St 1091+00 – 1106+00	▪ No information available
St 1106+00 – 1141+00	▪ Natural Ground (NG) to -53 ft - mostly clay/fine sand ▪ -53 ft to -58 ft – d50 = 0.21mm, 12% fines
St 1141+00 – 1159+00	▪ Material not compatible based on boring logs – mostly clay
St 1159+00 – 1188+00	▪ NG to -53 ft – d50 = 0.33 mm, 9% fines ▪ -53 to -56 ft – d50 = 0.4 mm, 7% fines ▪ One questionable boring to south of dredging extent
St 1188+00 – 1204+00	▪ NG to -51 ft – d50 = 0.11mm, 26% fines ▪ -51 to -56 ft – d50 = 0.15 mm, 30% fines
St 1204+00 – 1218+00	▪ NG to -56 ft – d50 = 0.22mm, 15% fines ▪ -56 to -62 ft – d50 = 0.24 mm, 10% fines
St 1218+00 – 1300+00	▪ NG to -62 ft – d50 = 0.35 mm, 5% fines
St 1300+00 – 1328+00	▪ Material not compatible based on boring logs – high percentage of fines

To compare the compatibility of this material with the native beach, the d50s and percentage fines (passing the #200 sieve) for the borings between stations 1106+00 to 1300+00, with the exception of the section between stations 1141+00 to 1159+00 were plotted against the native beach sand distributions (See **Figure 1-12**).

To compute the overfill factors at these locations, it was necessary to develop a grain size distribution from the available data presented in **Figure 1-12**. Two methodologies were used to approximate grain size distributions for each of the locations. For both methodologies the shape of the grain size distribution was approximated from the VIMS Boring WB097 grain size distribution using the sample ranging from elevation -50 to -55 ft (See **Figure 1-8**). This distribution was selected based on the results of the previous analysis of both borings WB097 and WB096. Given the overfill factors which were calculated and verified (see **Table 1-2**), the upper sample of WB097, ranging from -50 to -55 ft, was selected since it would be the most conservative estimate of the suitability of the material in Thimble Shoal Channel. This sample had the highest overfill factor of those analyzed, therefore, selecting one of the other samples may have resulted in idealistic compatibility results. Furthermore, boring WB097 was located within the channel and is therefore a more accurate estimate of the material present. The methodologies used for creating distributions from the USACOE sample point data are as follows.

- Method 1: The differences between the phi-size of the particle corresponding to the 50% retained and the % fines retained for a given USACOE sample and the VIMS WB097 distribution were computed. The differences (in phi units) were then interpolated for intermediate points (between the % fines and d50) and extrapolated for points along the curve beyond the known points at the % fines and the d50 to yield a shifted distribution. This shifted distribution became the phi-scale distribution for a given USACOE sample. An example of the shifted grain size distribution approximated using this method is shown on **Figure 1-13** for Station 1218+00 to 1300+00. The characteristics required for calculating the overfill factors were estimated from each shifted sample curve. The results of the analysis based on Method 1 are presented in **Table 1-5**.

Table 1-5 Overfill Factors Based on USACOE Borings – Method 1

		NATIVE BEACH		BORROW SOURCE		
Station Range	**Depth of Sample**	$M_{\varphi n}$	$\sigma_{\varphi n}$	$M_{\varphi b}$	$\sigma_{\varphi b}$	R_A
1106+00 – 1141+00	-53 to -58	2.10	0.73	2.12	1.53	1.37
1159+00 - 1188+00	NG to -53	2.10	0.73	1.48	2.02	1.26
	-53 to -56	2.10	0.73	1.20	2.12	1.22
1188+00 – 1204+00	NG to -51	2.10	0.73	3.06	0.94	4.34
	-51 to -56	2.10	0.73	2.61	1.80	1.73
1204+00 – 1218+00	NG to -56	2.10	0.73	2.06	1.73	1.39
	-56 to -62	2.10	0.73	1.94	1.69	1.33
1218+00 – 1300+00	NG to -62	2.10	0.73	1.39	1.81	1.20

- Method 2: As done for Method 1, the differences between the phi-size of the particle corresponding to the 50% retained and the % fines retained for a given USACOE sample and the VIMS WB097 distribution were computed. The average of these differences (50% retained and corresponding % fines) was computed, and the intact VIMS WB097 curve was shifted by this average difference. By this methodology, the resulting distribution maintained the same shape as the VIMS WB097 distribution. This shifted distribution became the phi-scale distribution for a given USACOE sample. An example of the shifted grain size distribution approximated using this method is shown on **Figure 1-14** for Station 1218+00 to 1300+00.The characteristics required for calculating the overfill factors were estimated from each shifted sample curve. The results of the analysis based on Method 2 are presented in **Table 1-6.**

Table 1-6 Overfill Factors Based on USACOE Borings – Method 2

		NATIVE BEACH		BORROW SOURCE		
Station Range	**Depth of Sample (ft)**	$M_{\varphi n}$	$\sigma_{\varphi n}$	$M_{\varphi b}$	$\sigma_{\varphi b}$	R_A
1106+00 – 1141+00	-53 to -58	2.10	0.73	2.23	1.29	1.36
1159+00 - 1188+00	NG to -53	2.10	0.73	1.88	1.12	1.12
	-53 to -56	2.10	0.73	1.67	1.12	1.07
1188+00 – 1204+00	NG to -51	2.10	0.73	2.83	1.28	1.99
	-51 to -56	2.10	0.73	2.77	1.29	1.88
1204+00 – 1218+00	NG to -56	2.10	0.73	2.25	1.31	1.37
	-56 to -62	2.10	0.73	2.08	1.23	1.25
1218+00 – 1300+00	NG to -62	2.10	0.73	1.65	1.12	1.06

As a final verification for using the VIMS boring WB097 to generate the USACOE grain size distributions, Method 2 was repeated using the VIMS boring WB096 distribution, and both the Sediment Y and Sediment Z grain size distributions from the Waterway report. Shifted USACOE curves were generated for the station range of 1218+00 to 1300+00 based on each distribution. Since the depth of the USACOE sample for this section ranged from natural ground to -62 ft, a representative VIMS WB096 distribution which was the average of the three samples taken from -44 ft to -60 ft was used for generating the USACOE curve. Once the shifted curves were generated, the overfill factors were computed (see **Table 1-7**).

Table 1-7 Overfill Factors Based on USACOE Borings – Method 2 Verification

			NATIVE BEACH		BORROW SOURCE		
Station Range	**Curve Used**	**Depth of Sample (ft)**	$M_{\varphi n}$	$\sigma_{\varphi n}$	$M_{\varphi b}$	$\sigma_{\varphi b}$	R_A
1218+00 – 1300+00	VIMS WB096 (Avg -44 to -60 ft)	NG to -62	2.10	0.73	1.97	0.88	1.04
	Sediment Y (NG to -55 ft)	NG to -62	2.10	0.73	1.57	1.30	1.10
	Sediment Z (NG to -55 ft)	NG to -62	2.10	0.73	1.73	1.05	1.06

As shown on **Table 1-7**, the resulting overfill factors for the station range of 1218+00 to 1300+00 are not significantly different than those computed using the WB097 curve. Using the VIMS WB096 average curve, the overfill factor was lower than that computed using the WB097 curve. This was expected, since the previous analysis resulted in overfill factors which were lower for WB096 compared to a corresponding depth at WB097 (see **Table 1-2**). Since the potential beach fill material for this project is limited to the Thimble Shoal Channel dredging extent, the selection of the WB097 curve for approximating sand compatibility is further verified. The WB096 curve would have likely overstated the compatibility of the material present in the channel, based on these analyses.

The above results for the approximation of the USACOE curve based on the Waterway Sediment data indicates that the material on the east side of Thimble Shoal Channel (Sediment Z area) is more compatible than that on the west side of the channel (Sediment Y area). However, this is contrary to the preliminary overfill factors calculated for the Sediment Y and Sediment Z grain size distributions (see **Table 1-3**). The difference in these results is likely due to the methodology used to compute the composite distributions for Sediment Y and Sediment Z. As discussed, the composite distribution developed for Sediment Y was only based on three borings which were spaced a great distance from one another. This composite distribution may have discounted the presence of fines within the channel. Furthermore, there was not enough information on the source of the data used to develop the composite Sediment Z distribution to determine its direct compatibility with the native beach. However, the use of the WB097 curve is still verified by these results, since the overfill factors calculated for the station range of 1218+00 to 1300+00 were the same when approximated using the WB097 curve and the Sediment Z curve.

C. SANDBRIDGE SHOAL SEDIMENT ANALYSIS

The main data used for analyzing the compatibility of the borrow source at Sandbrige Shoal with East Ocean View Beach came from the USACOE's plans and specifications for beach erosion control and hurricane protection at Sandbridge Beach, Virginia (June 2002). The plans and specifications for this project included the delineation of several potential borrow areas located within Sandbridge Shoal. For each borrow area, a number of borings were collected and analyzed. The specifications included the phi-scale grain size distributions for these borings, as well as the boring logs. For each phi-scale grain size distribution, the median (d50), the mean (M_φ), and the standard deviation (σ_φ) of the distribution were defined.

Three borrow areas, defined as "A", "B" and "BB" were defined for the USACOE project on Sandbridge Beach. The locations of these borrow areas relative to the Virginia and Sandbridge Beaches, as well as to the East Ocean View Beach area, are shown on **Figure 1-15**. As shown on the figure, the borrow areas are intersecting the boundary of the Official Protraction Diagram (OPD) area. The OPDs are sub-blocks of the planning areas defined for the Atlantic Coast. The area offshore of Sandbridge are within the Currituck Sound OPD (NJ18-11). The boundary of this area begins approximately 3.0 to 3.5 miles offshore.

The compatibility analysis focused on the areas which were seaward of the boundary of the Currituck Sound OPD. This included all of borrow areas B and BB and a portion of borrow area A. Most of the borings taken in these borrow areas contained 1 or more sample depths for which grain size distributions and resulting statistics were computed. Given that the maximum allowable depth for excavation in Sandbridge Shoal is -48.4 ft MLLW (-50 ft NGVD 29), only samples above this depth were selected for analyses. **Figures 1-16** through **1-18** show the grain size distributions for corresponding samples in Borrow Areas A, B, and BB, respectively plotted against the native beach composite distribution. Based on this comparison of the grain size distributions, the material in borrow areas B and BB are more similar to the native beach material than that present in borrow area A. The grain size distributions for a majority of the boring samples within borrow areas B and BB are very similar in shape and gradation to the native beach composite distribution. With the exception of a few deeper samples, the material in these areas appears to be slightly coarser than the native beach material.

To furthur evaluate the compatibility of the material present in the borrow areas in Sandbridge Shoal with the East Ocean View Beach sand, the overfill factors were calculated. Since the USACOE project specifications also included the mean (M_φ) and standard deviations (σ_φ) for each of the grain size distributions analyzed, the overfill factors could be calculated easily. **Table 1-8** shows the resulting overfill factors for the selected samples in the three Sandbridge Shoal borrow areas.

Table 1-8 Overfill Factors Based on USACOE's Sandbridge Shoal Data

Borrow Area A

		NATIVE BEACH		BORROW SOURCE		
Boring #	**Depth of Sample**	$M_{\varphi n}$	$\sigma_{\varphi n}$	$M_{\varphi b}$	$\sigma_{\varphi b}$	R_A
SBVC16	-42.45 to -46.75	2.10	0.73	2.34	0.68	1.65
	-46.75 to -48.45	2.10	0.73	1.23	2.28	1.26
SBVC17	-39.95 to -44.95	2.10	0.73	2.10	0.59	1.16
	-44.95 to -49.95	2.10	0.73	1.99	1.09	1.15

Borrow Area B

		NATIVE BEACH		BORROW SOURCE		
Boring #	**Depth of Sample**	$M_{\varphi n}$	$\sigma_{\varphi n}$	$M_{\varphi b}$	$\sigma_{\varphi b}$	R_A
SBVC7	-35.75 to -40.75	2.10	0.73	1.57	0.59	1.00
	-40.75 to -45.75	2.10	0.73	2.18	0.66	1.21
SBVC11	-36.35 to -41.35	2.10	0.73	1.22	0.78	1.00
	-41.35 to -46.35	2.10	0.73	1.43	0.73	1.00
	-46.35 to -51.35	2.10	0.73	1.74	0.68	1.00
SBVC12	-39.95 to -44.95	2.10	0.73	1.60	0.62	1.00
	-44.95 to -49.95	2.10	0.73	2.11	0.60	1.18
SBVC13	-41.35 to -46.35	2.10	0.73	1.82	0.64	1.00
	-46.75 to -48.35	2.10	0.73	2.30	0.59	1.85
SBVC39	-40.95 to -45.95	2.10	0.73	1.58	0.72	1.00
	-45.95 to -50.35	2.10	0.73	2.16	0.46	2.01
SBVC49	-38.75 to -44.75	2.10	0.73	1.47	0.72	1.00
	-44.75 to -50.75	2.10	0.73	1.87	0.65	1.00
SBVC50	-45.55 to -48.45	2.10	0.73	1.68	0.60	1.00

Borrow Area BB

		NATIVE BEACH		BORROW SOURCE		
Boring #	**Depth of Sample**	$M_{\varphi n}$	$\sigma_{\varphi n}$	$M_{\varphi b}$	$\sigma_{\varphi b}$	R_A
SBVC8	-37.25 to -42.25	2.10	0.73	1.67	0.69	1.00
	-42.25 to -45.25	2.10	0.73	2.57	0.57	6.30
SBVC10	-40.15 to -45.15	2.10	0.73	1.56	0.64	1.00
	-45.15 to -48.65	2.10	0.73	1.69	0.76	1.00
SBVC24	-46.95 to -51.35	2.10	0.73	1.60	0.59	1.00
SBVC25	-39.05 to -44.05	2.10	0.73	1.36	0.56	1.00
	-44.05 to -49.05	2.10	0.73	1.40	0.63	1.00
SBVC65	-38.25 to -43.25	2.10	0.73	1.53	0.63	1.00

Based on the overfill factors shown in **Table 1-8**, Borrow Areas B and BB are again determined to be more compatible with the native beach than Borrow Area A. Within Borrow Areas B and BB, it appears that the most compatible sand is above elevation -45 ft, since the overfill factor for several borings (e.g. 95SBVC12, 95SBVC13, 95SBVC39) increases significantly below this elevation. Furthermore, the easternmost borings (95SBVC7 and 95SBVC8) have significantly higher overfill factors below elevation -40 ft. Therefore, it may be best to avoid using the material near these boring locations altogether. Overall, given that the overfill factors are all 1.00 within the compatible areas and above elevation -45 ft, Sandbridge Shoal has material which is suitable for beach fill on East Ocean View Beach.

D. SELECTION OF SUITABLE BORROW MATERIAL FROM THIMBLE SHOAL CHANNEL DREDGING PROJECT EXTENTS

Given the results of the compatibility analysis between the potential borrow site at Thimble Shoal Channel and the native beach material on East Ocean View Beach, a decision on the location of the most suitable borrow material within the USACOE dredging project extent could now be made. The USACOE CEM gives the following guidelines for selecting suitable borrow material for beach fill:

> "*As a general recommendation, a nourishment project should use fill material with a composite mean grain diameter equal to that of the native beach material, and with an overfill factor within the range of 1.00 to 1.05. This is the optimal level of sediment compatibility. However, obtaining this level of compatibility is not always possible due to limitations in available borrow sites...Borrow material that is coarser than the native material will produce a beach which is at least as stable as a fill comprised of native beach material.*"(EM1110-2-1100 (Part V), PGS. V-4-24-25)

As shown in **Table 1-2**, the overfill factors computed using the sediment data from the VIMS boring WB097 are 1.10 for the -50 to -55 ft sample, and 1.00 for the -55 to -60 ft sample. The overfill factors computed from the USACOE boring data (approximated grain size distributions) using both Methods 1 and 2, are generally greater than the optimal range as defined by the USACOE. The main reason that the overfill factors are higher is due to the larger percentage of fines found in the USACOE borings. This is expected given that higher percentages of fines are usually found in channels in comparison to their neighboring banks. The VIMS boring WB097 did not account for the pockets of fines present in the channel, because it was at a discrete location. In fact, the percentage of fines at the USACOE boring which was closest to the VIMS boring WB097 was less than 6 %. However, it is important to note that higher percentages of fines will be encountered within the dredging project extent, as evidenced by the resulting overfill factors calculated for the USACOE borings. Fines which are present in the beach fill material will be carried offshore quickly, but the coarser d50s should provide somewhat of an armouring effect during future storm events.

Given the resulting overfill factors shown in **Tables 1-5** and **1-6**, the range of stations and depths selected as the most suitable for borrow material are the following:

1159+00 – 1188+00	Natural Ground to -56 ft
1204+00 – 1218+00	Natural Ground to -62 ft
1218+00 – 1300+00	Natural Ground to -62 ft

The section of borrow material between Station 1106+00 to 1141+00 was not selected because of a top layer of fines/clays present to elevation -53 ft and spotty material below that.

As shown on the permit drawings, the required fill quantity for this project is approximately 370,000 yd^3. To finalize the dredging depths for these locations of suitable borrow material, the latest survey of the channel was placed in the AutoCad LDD software package. Using this survey, various channel depths were tested to determine available quantities. **Table 1-5** shows the resulting available quantities for the tested depths.

Table 1-8 Dredging Quantities Available at Various Channel Depths
<u>Cumulative</u> Dredge Quantities in Cubic Yards

Station	-51 ft	-52 ft	-53 ft	-54 ft	-55 ft	-56 ft	-57 ft	-58 ft
1106+00 - 1141+00	26,853	55,588	99,605	147,331	196,323	246,173	296,840	348,304
1141+00 - 1158+00	36,782	57,469	81,205	105,367	129,936	154,914	180,299	206,087
1159+00 - 1188+00	89,228	127,538	168,748	211,208	254,357	298,185	342,695	387,893
1188+00 - 1204+00	29,873	40,370	52,137	64,948	78,455	92,447	106,799	121,502
1204+00 - 1218+00	12,615	18,774	25,851	33,965	42,922	52,275	61,950	71,943
1218+00 - 1300+00	12,862	26,914	48,492	77,283	112,229	151,273	192,637	235,862
TOTAL	208,214	326,653	476,039	640,102	814,223	995,267	1,181,219	1,371,591
TOTAL (1159+00-1188+00 & 1204+00-1300+00)	114,706	173,226	243,092	322,457	409,508	501,733	597,282	695,698

In conclusion, it would appear that in utilizing the preferred sections between station 1159+00 to 1188+00 and station 1204+00 to 1300+00, the required project quantity should be met by dredging these areas to -55 ft. Using the normal 1 ft allowable overdredge, the project quantity should be easily met and would also allow for a factor of safety if some unforeseen pockets of silts/muds or shell hash are encountered. The dredge could then be directed to move to a different area if needed. In fact, given the age of these borings and the concern of % fines shown in the USACOE borings, the most prudent course of action would be to identify the preferred channel sections as primary borrow areas while denoting the remaining sections of the channel as secondary borrow areas. The contractor could then concentrate in the primary borrow areas and only move to the secondary areas if unforeseen pockets of material are found in the primary areas. These areas are shown in detail on the separately submitted dredging drawings as part of this package.

II. REFERENCES

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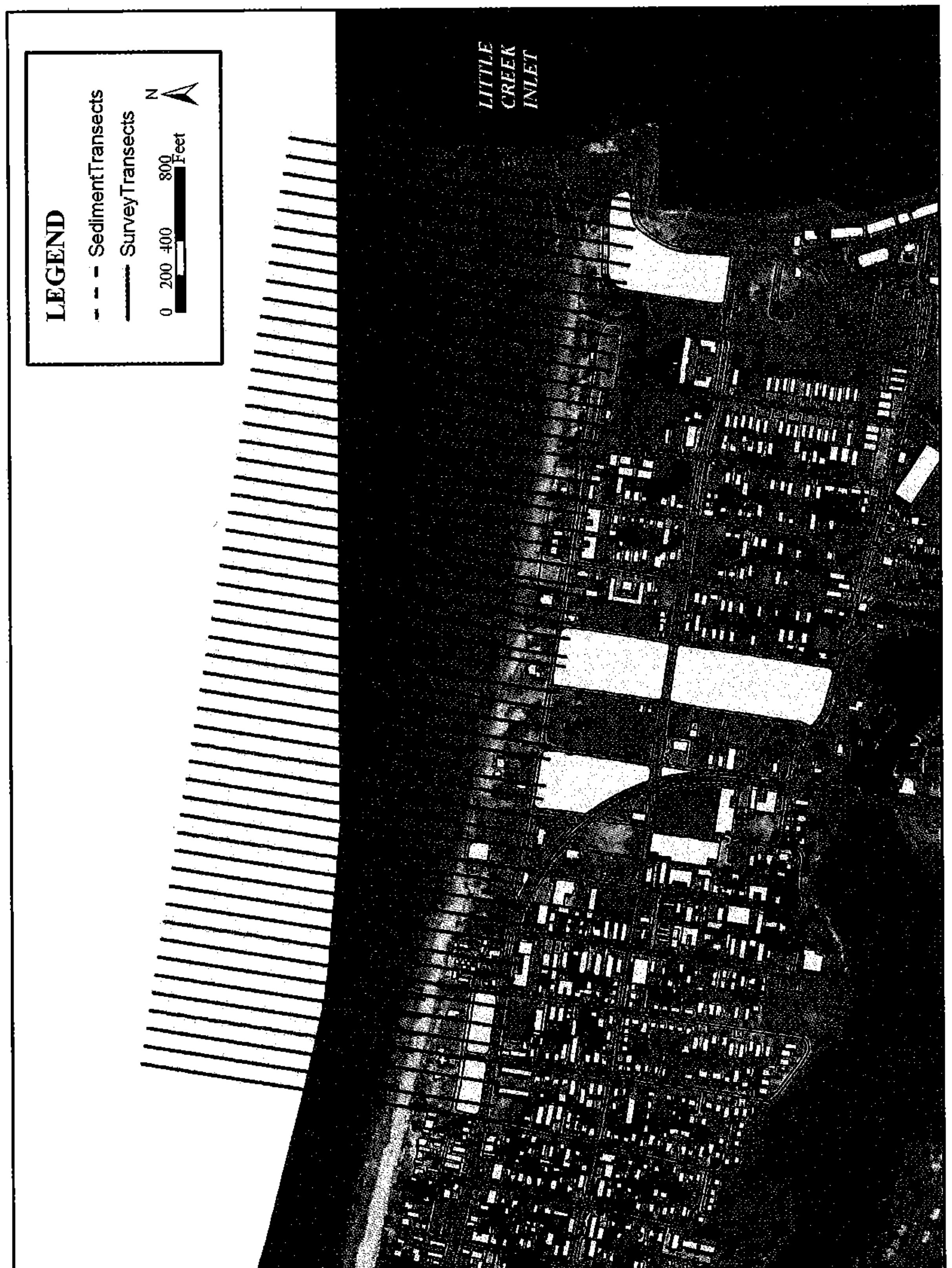

Figure 1-1 Location of Sediment Sample Transects

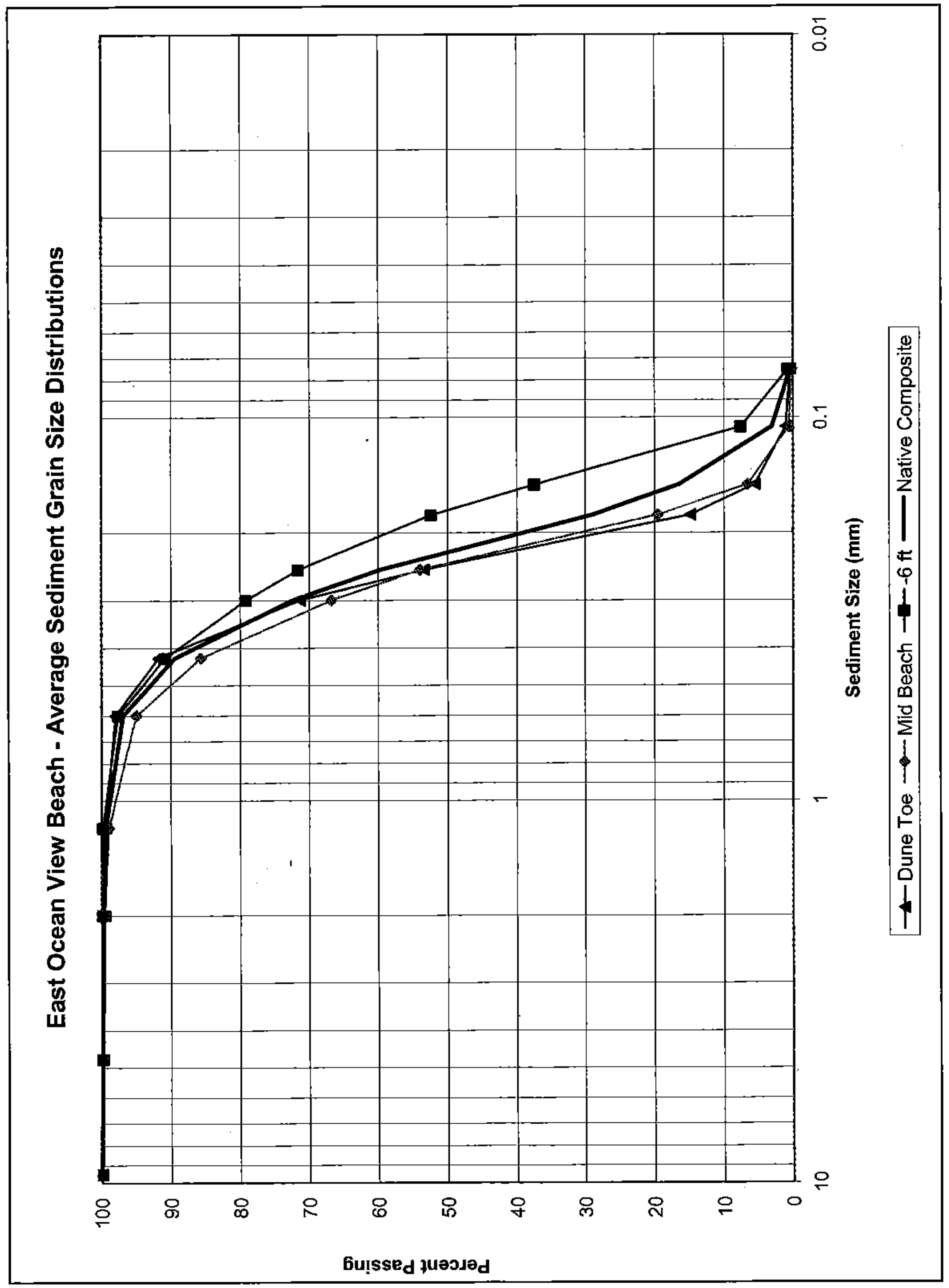

Figure 1-2 Average Sediment Grain Size Distributions and Resulting Composite Distribution for East Ocean View Beach

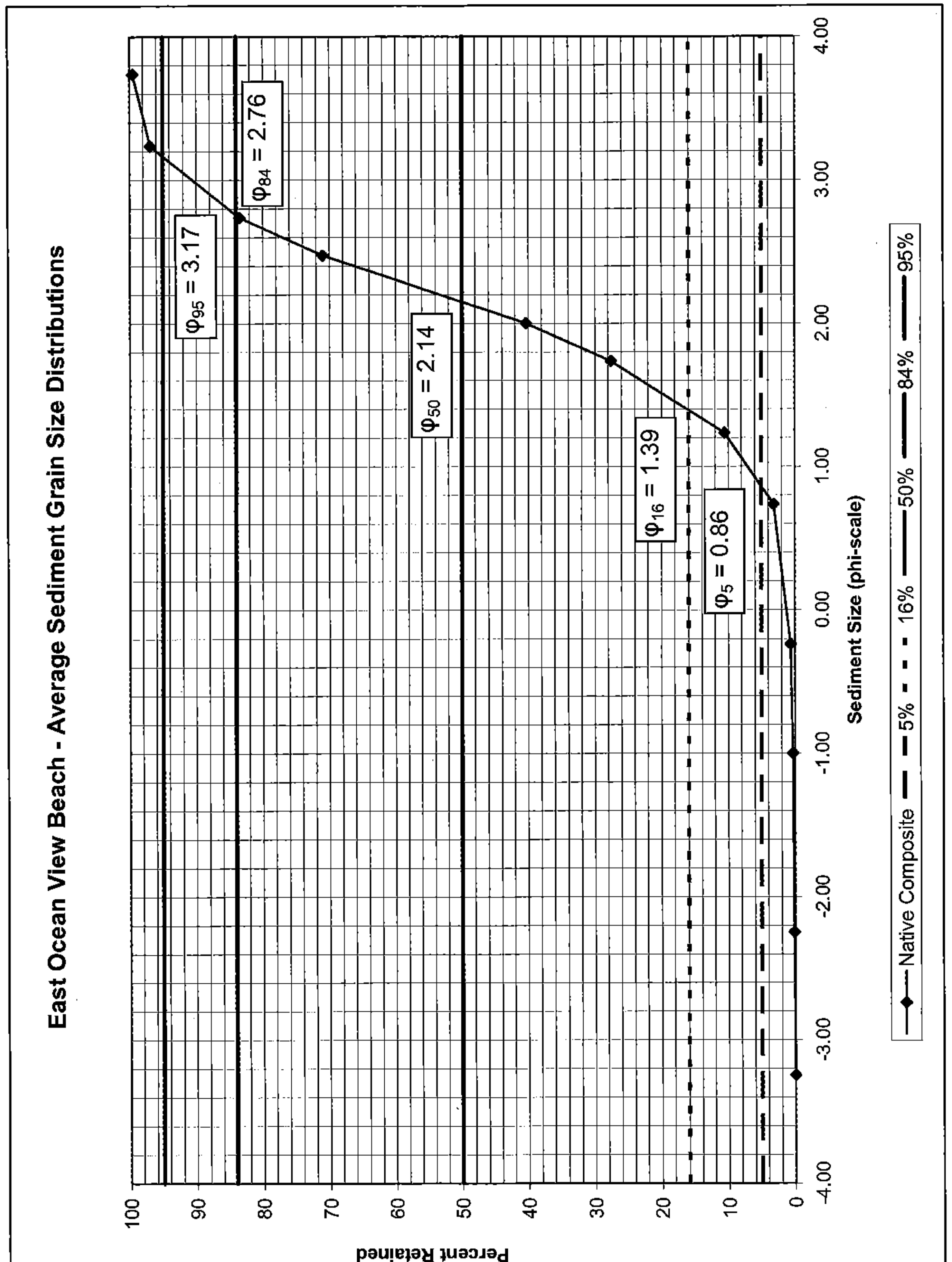

Figure 1-3 Phi-Scale Composite Grain Size Distribution for East Ocean View Beach

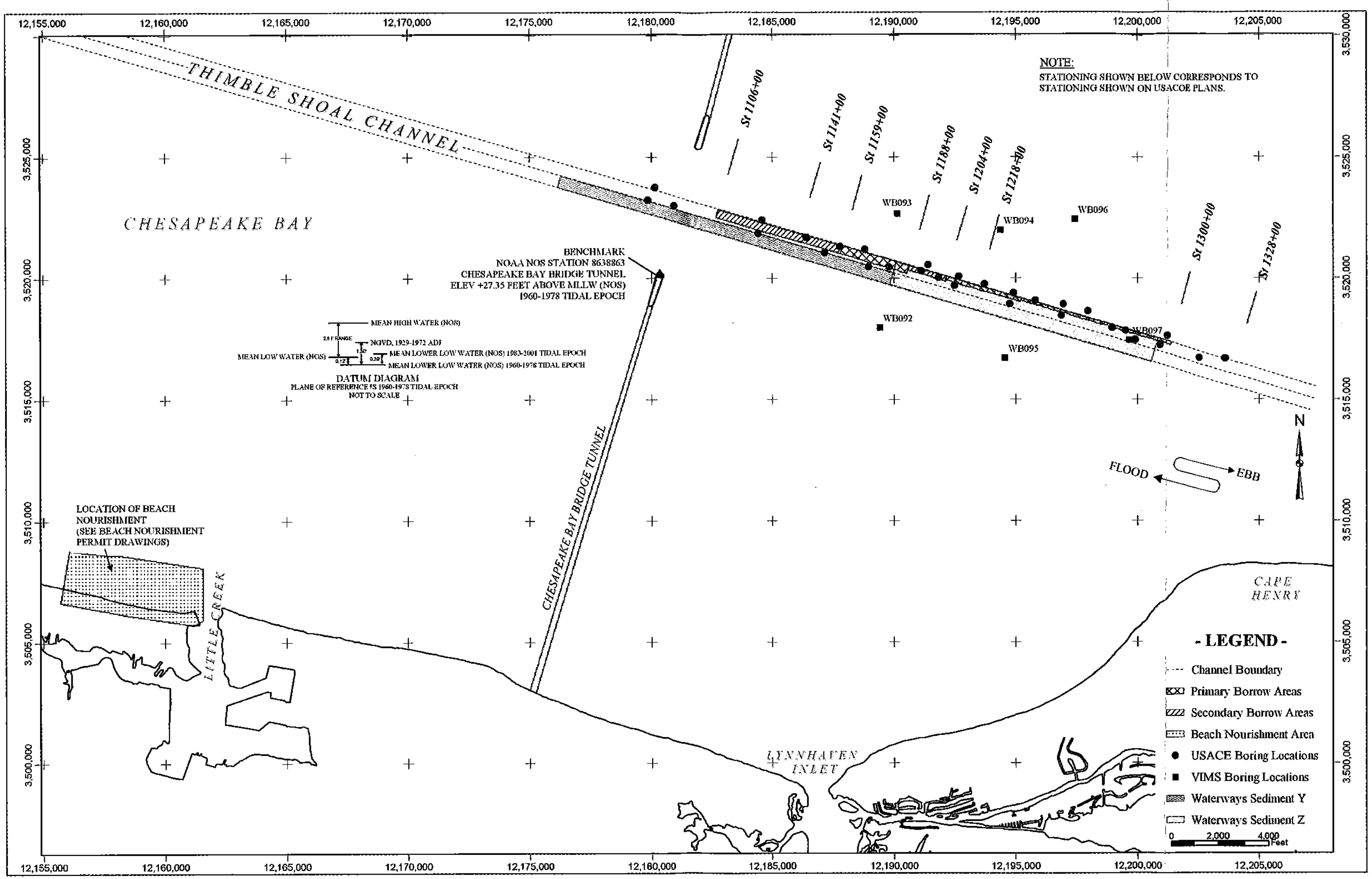

Figure 1-4 Location of VIMS, Waterway, and USACOE Sediment Borings in and near Thimble Shoal Channel

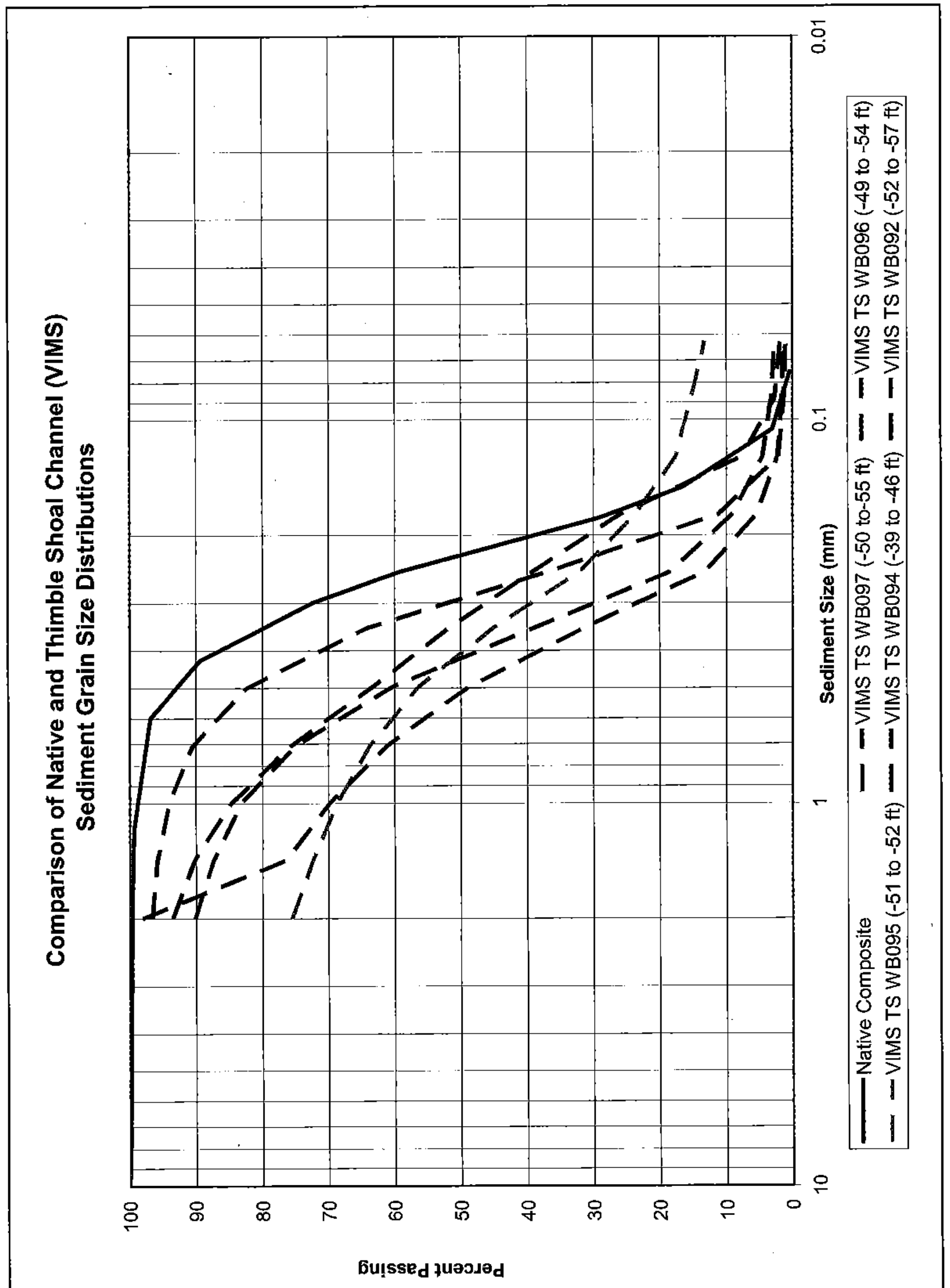

Figure 1-5 Comparison of Native Composite and Selected VIMS Sediment Grain Size Distributions

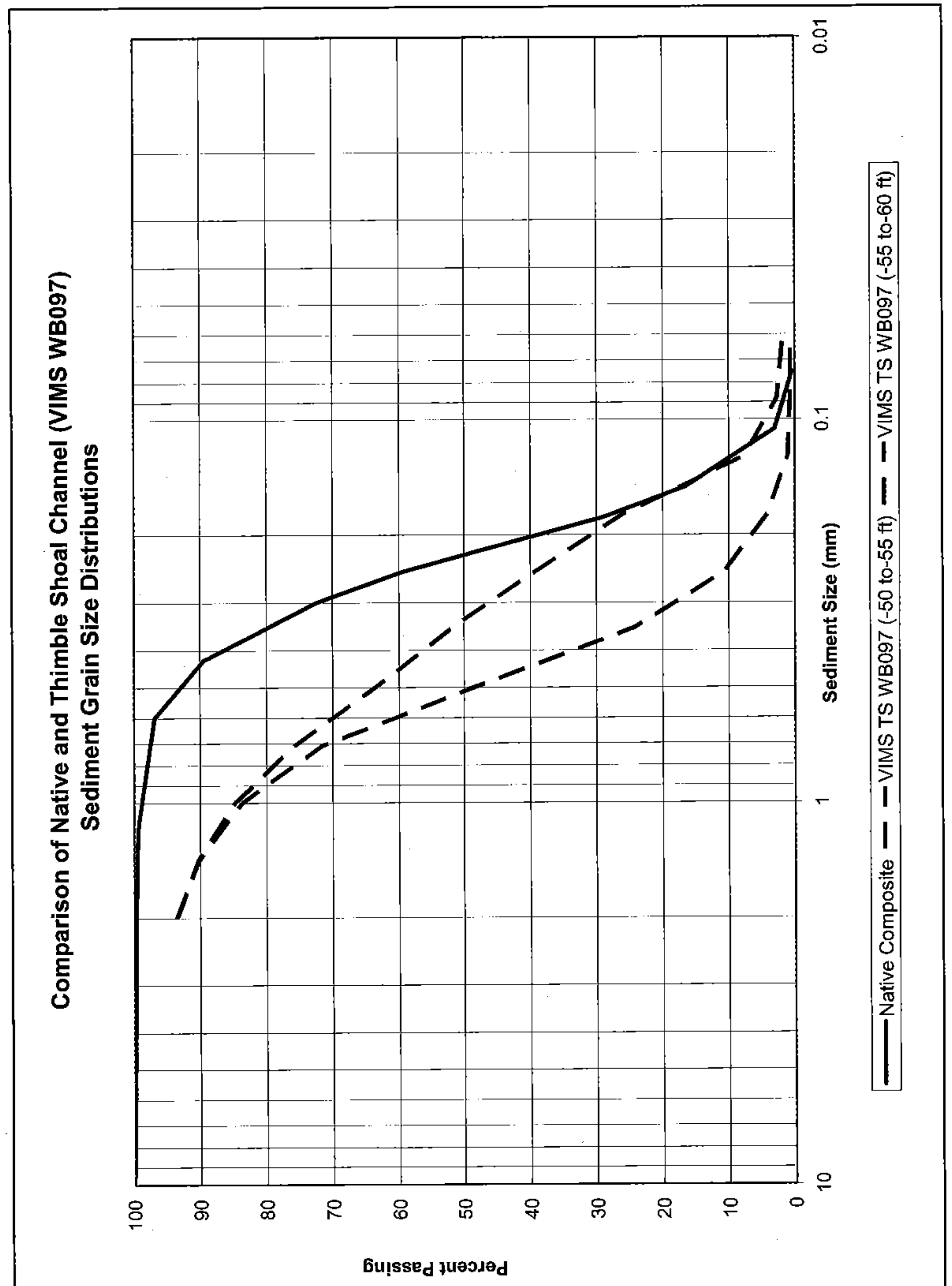

Figure 1-6 Comparison of Native Composite and VIMS WB097 Sediment Grain Size Distributions

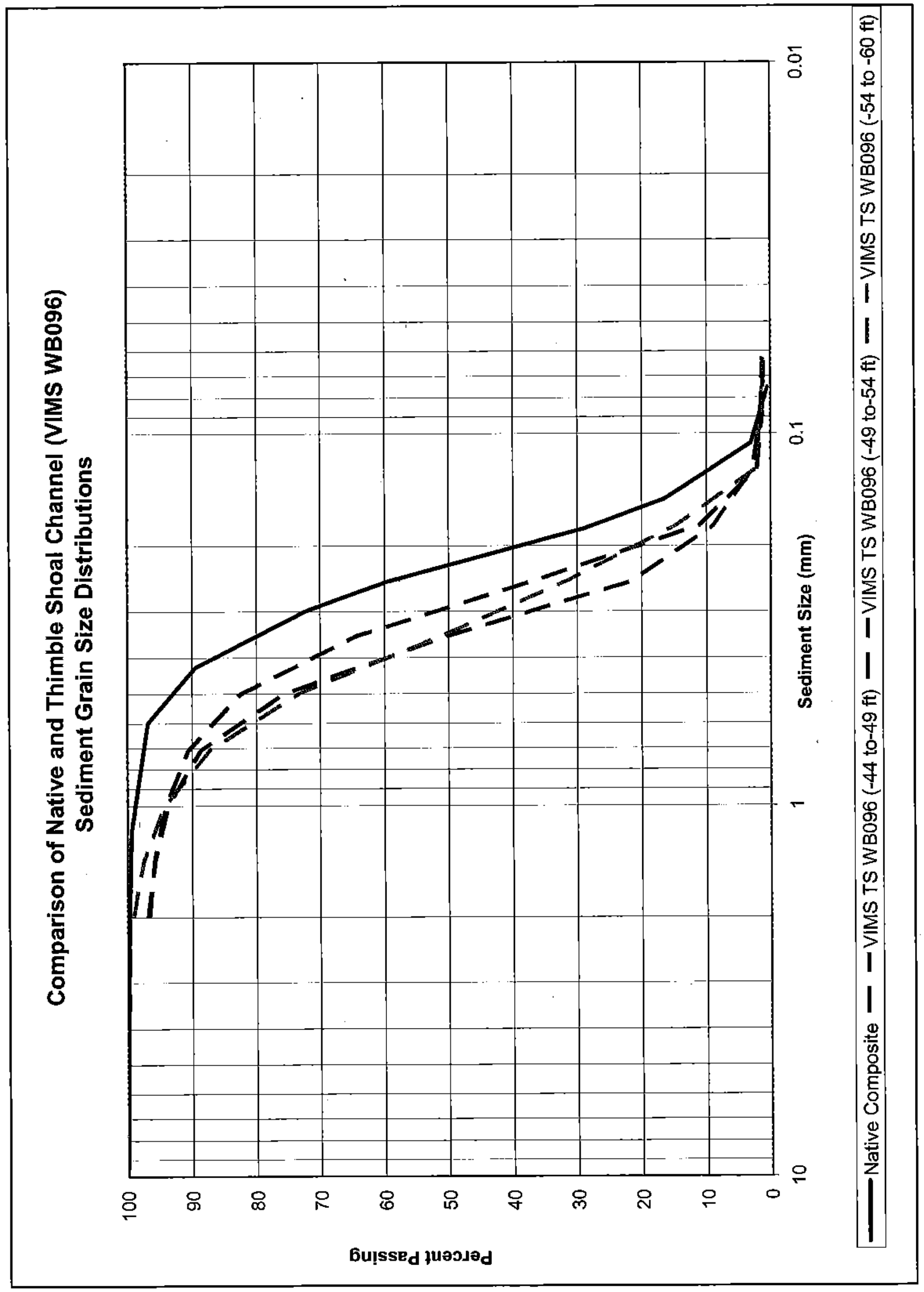

Figure 1-7 Comparison of Native Composite and VIMS WB096 Sediment Grain Size Distributions

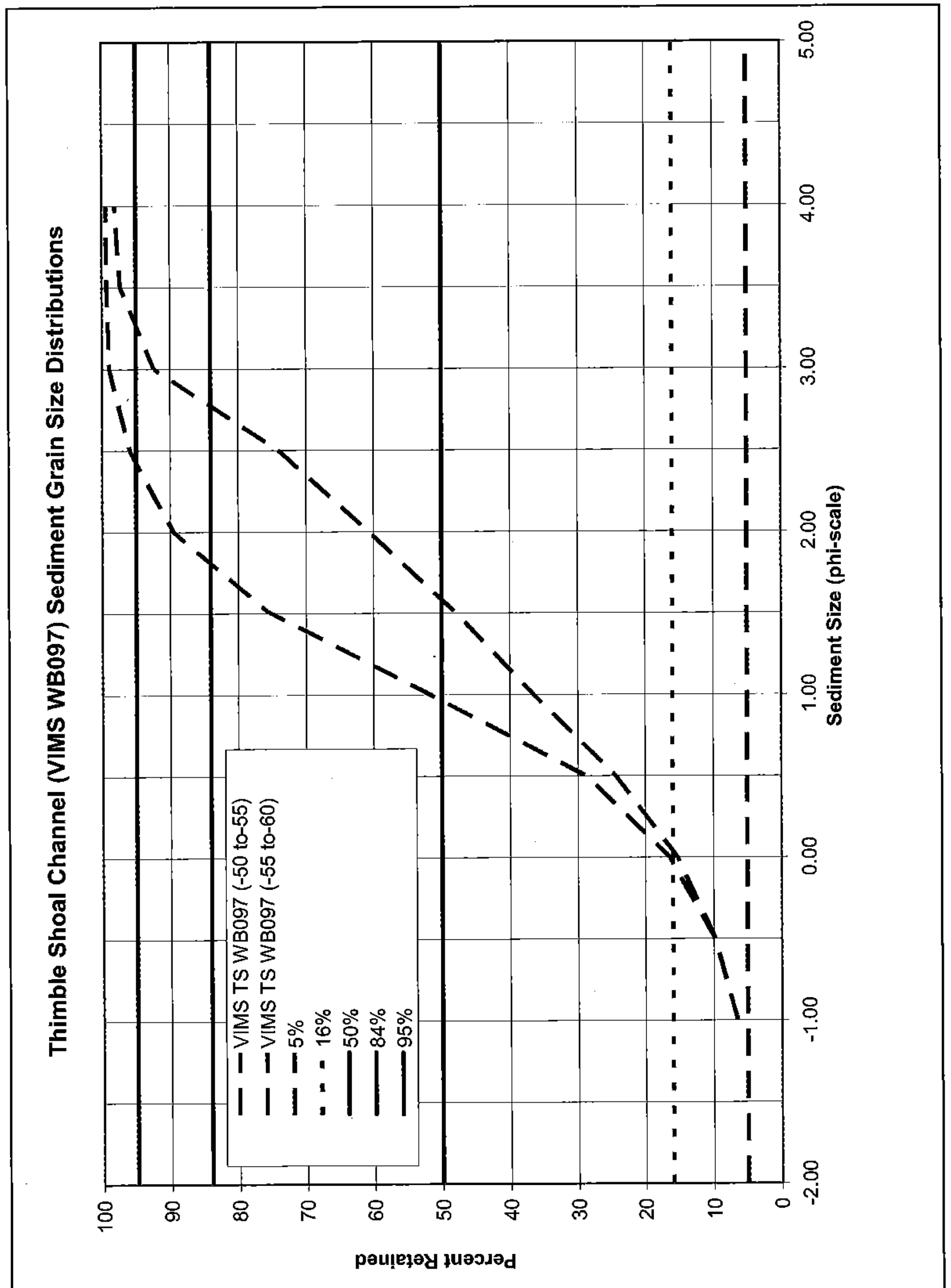

Figure 1-8 Phi-Scale Sediment Grain Size Distributions for VIMS WB097 Borings

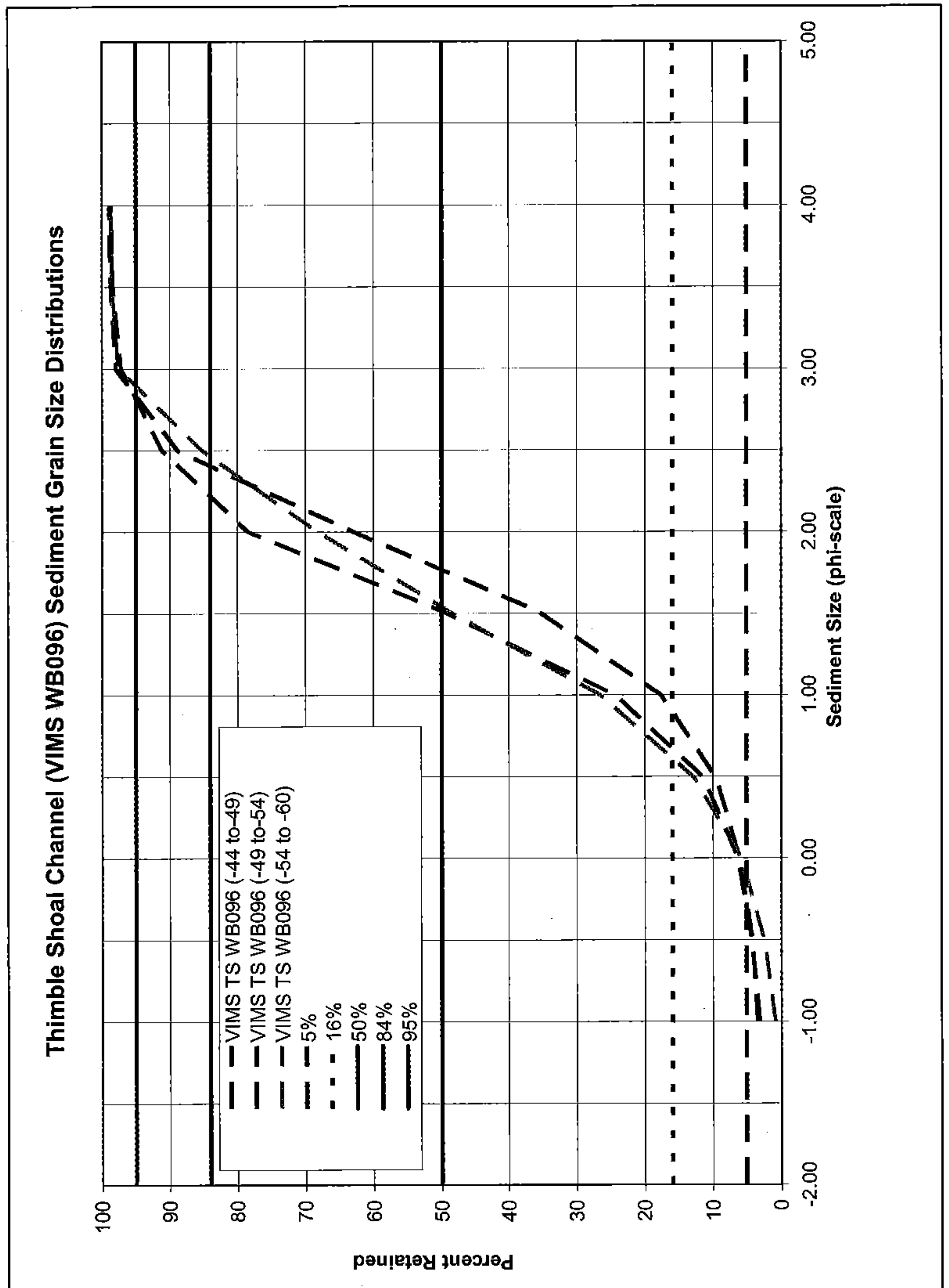

Figure 1-9 Phi-Scale Sediment Grain Size Distributions for VIMS WB096 Borings

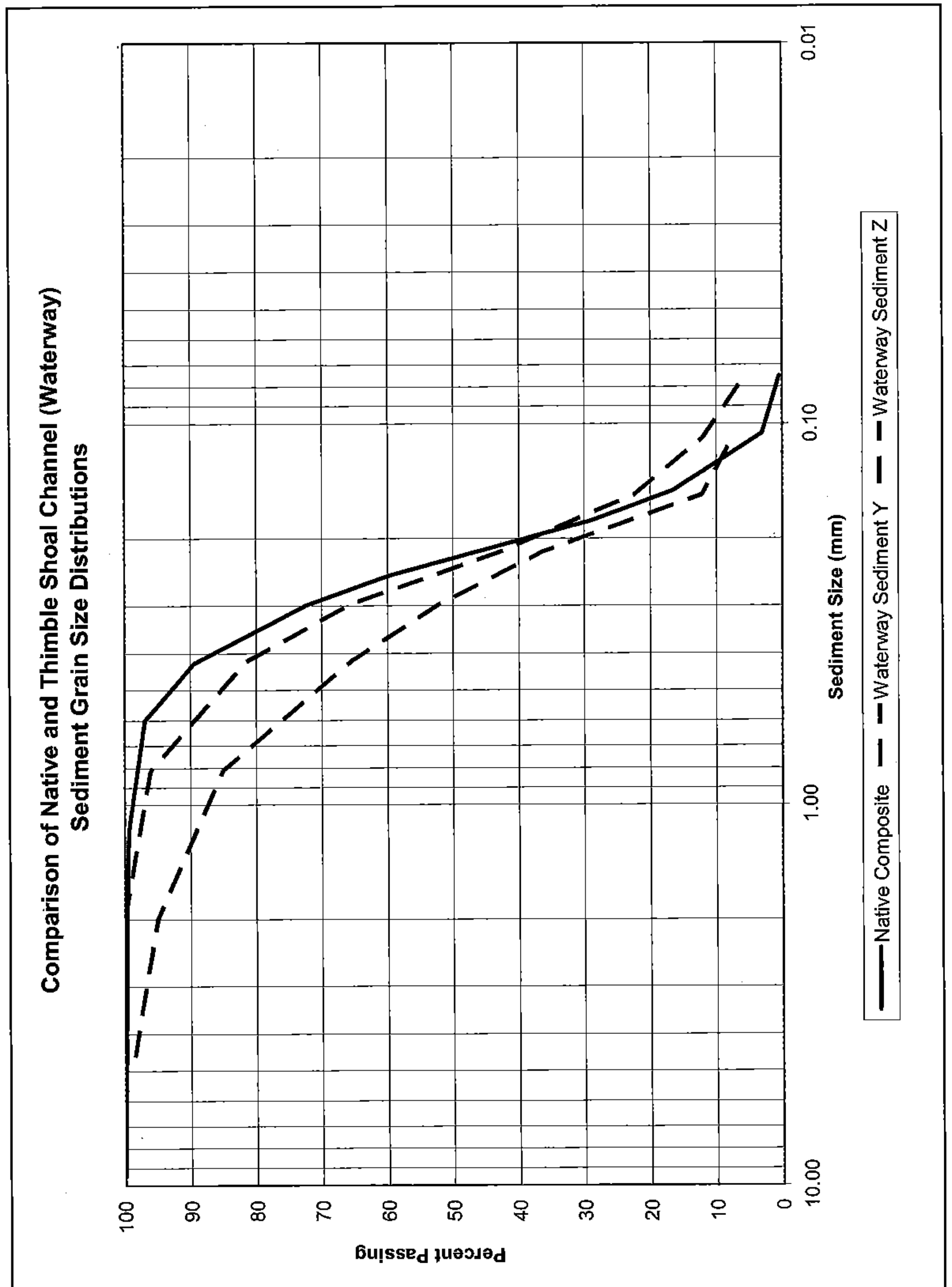

Figure 1-10 Comparison of Native Composite and Waterway Sediment Y and Sediment Z Grain Size Distributions

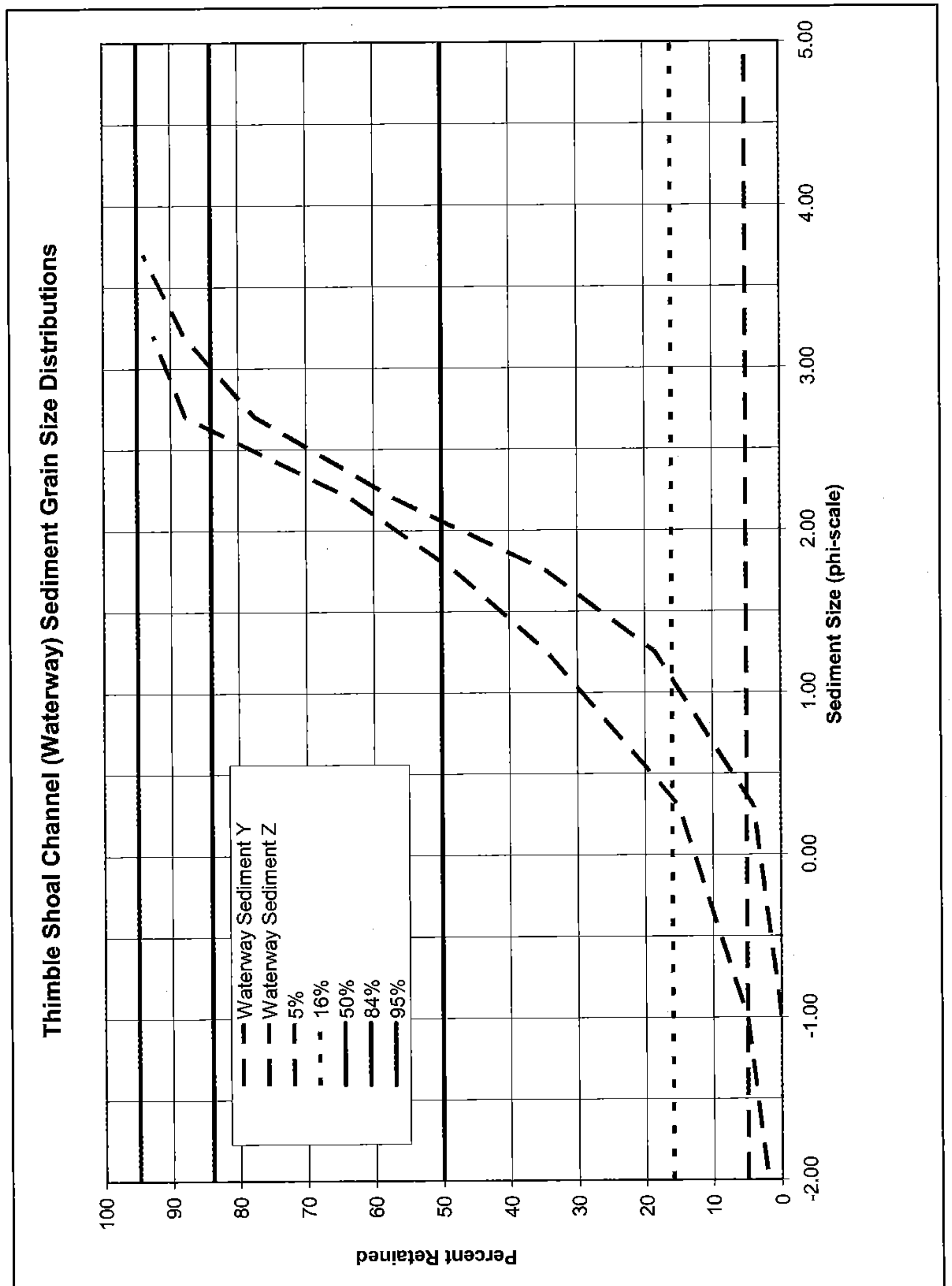

Figure 1-11 Phi-Scale Sediment Grain Size Distributions for Waterway Sediment Y and Sediment Z

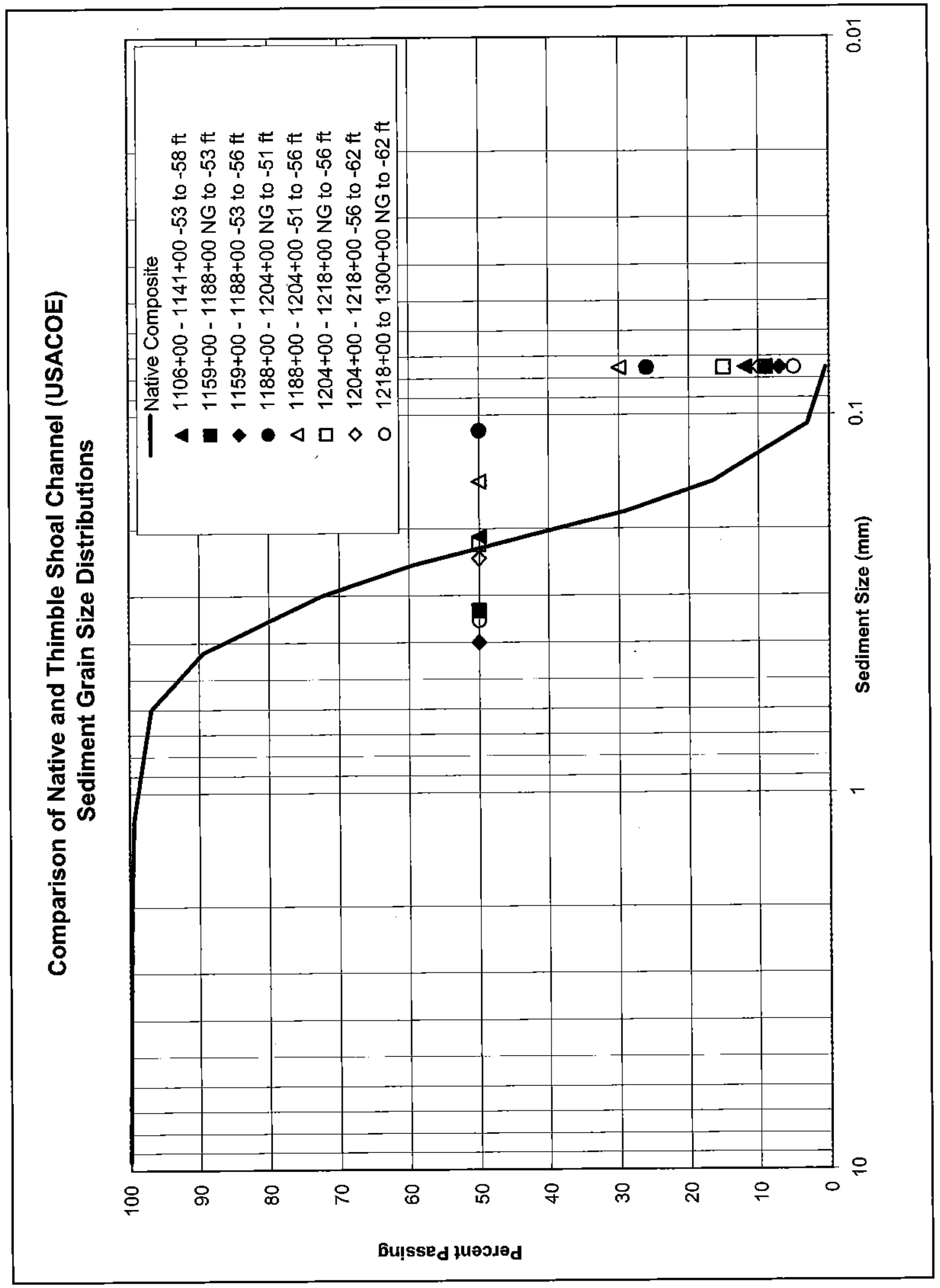

Figure 1-12 Comparison of Native Composite and USACOE Sediment Data

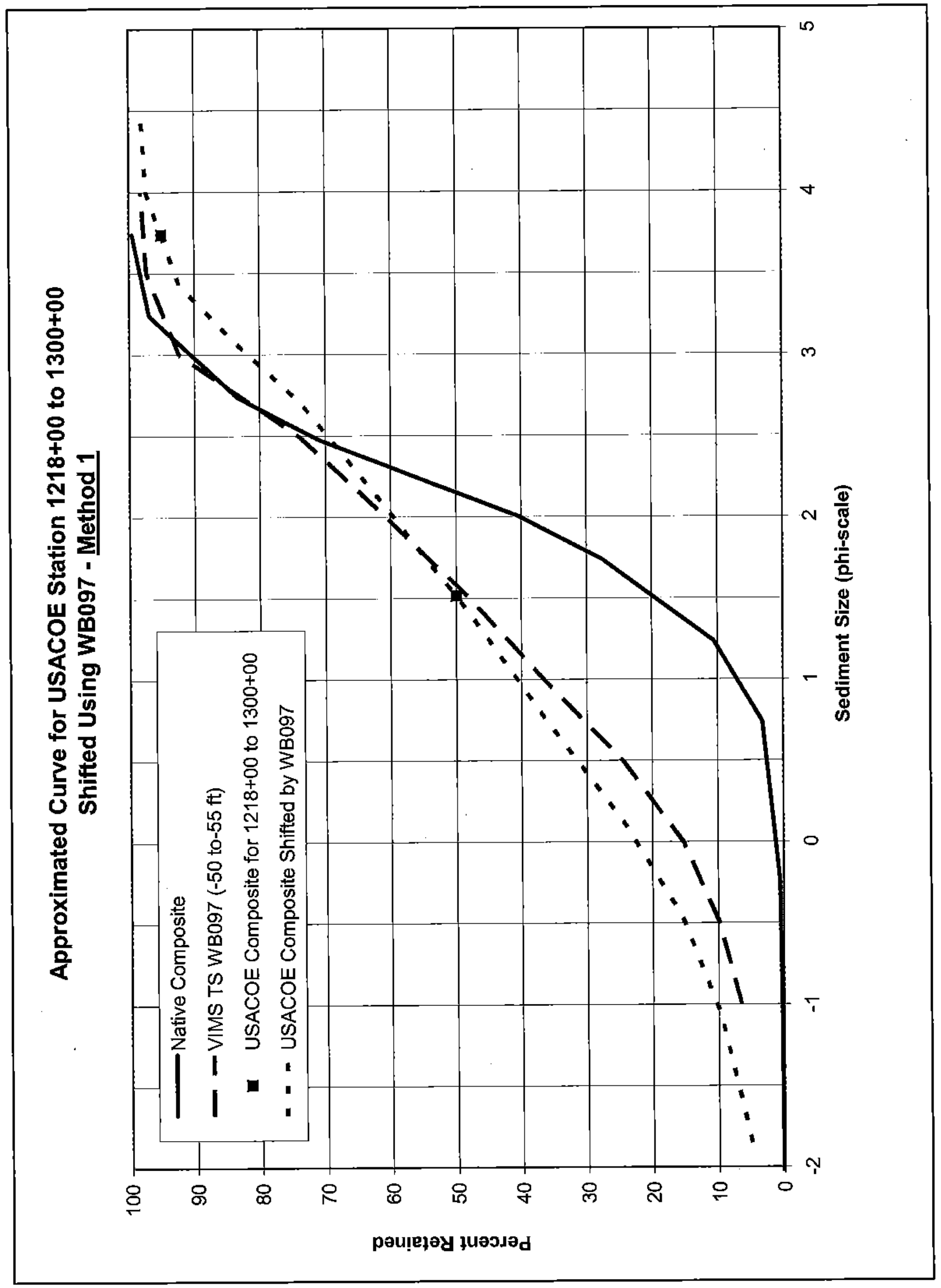

Figure 1-14 Example of Method 1 for Approximation of USACOE Grain Size Distribution for Station 1218+00 to 1300+00

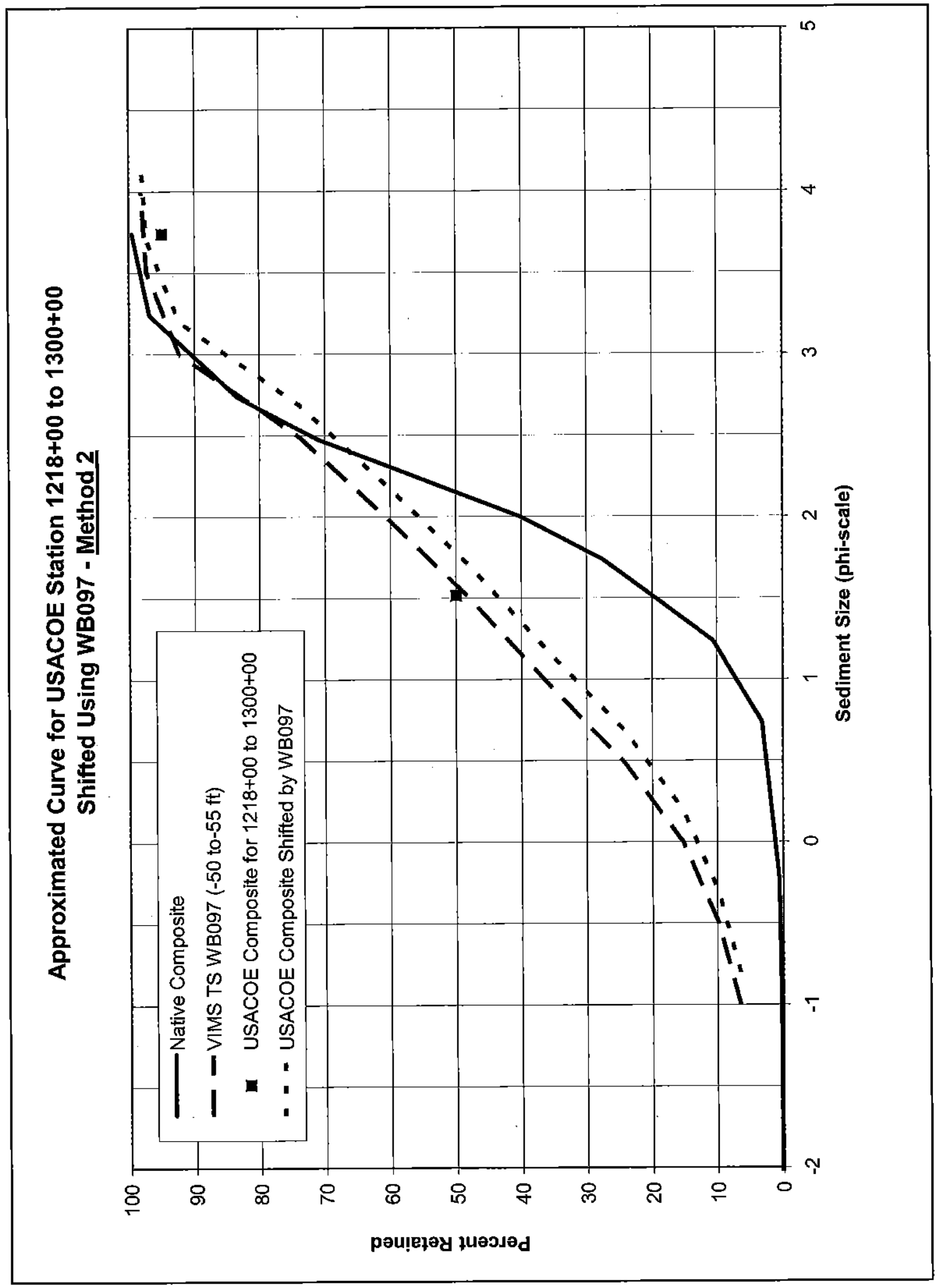

Figure 1-14 Example of Method 2 for Approximation of USACOE Grain Size Distribution for Station 1218+00 to 1300+00

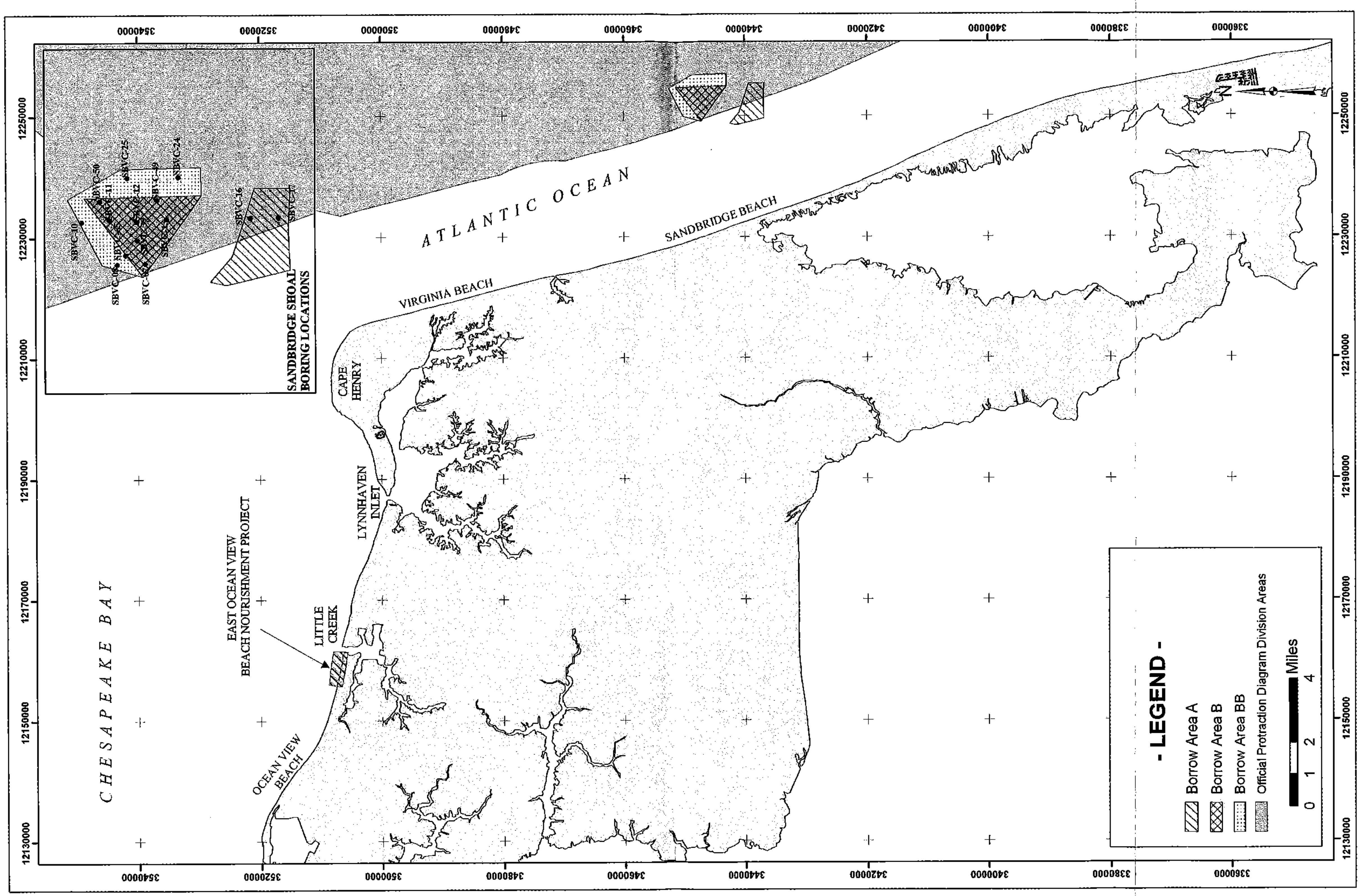

Figure 1-15 Location of Sandbridge Shoal Borrow Areas and Borings

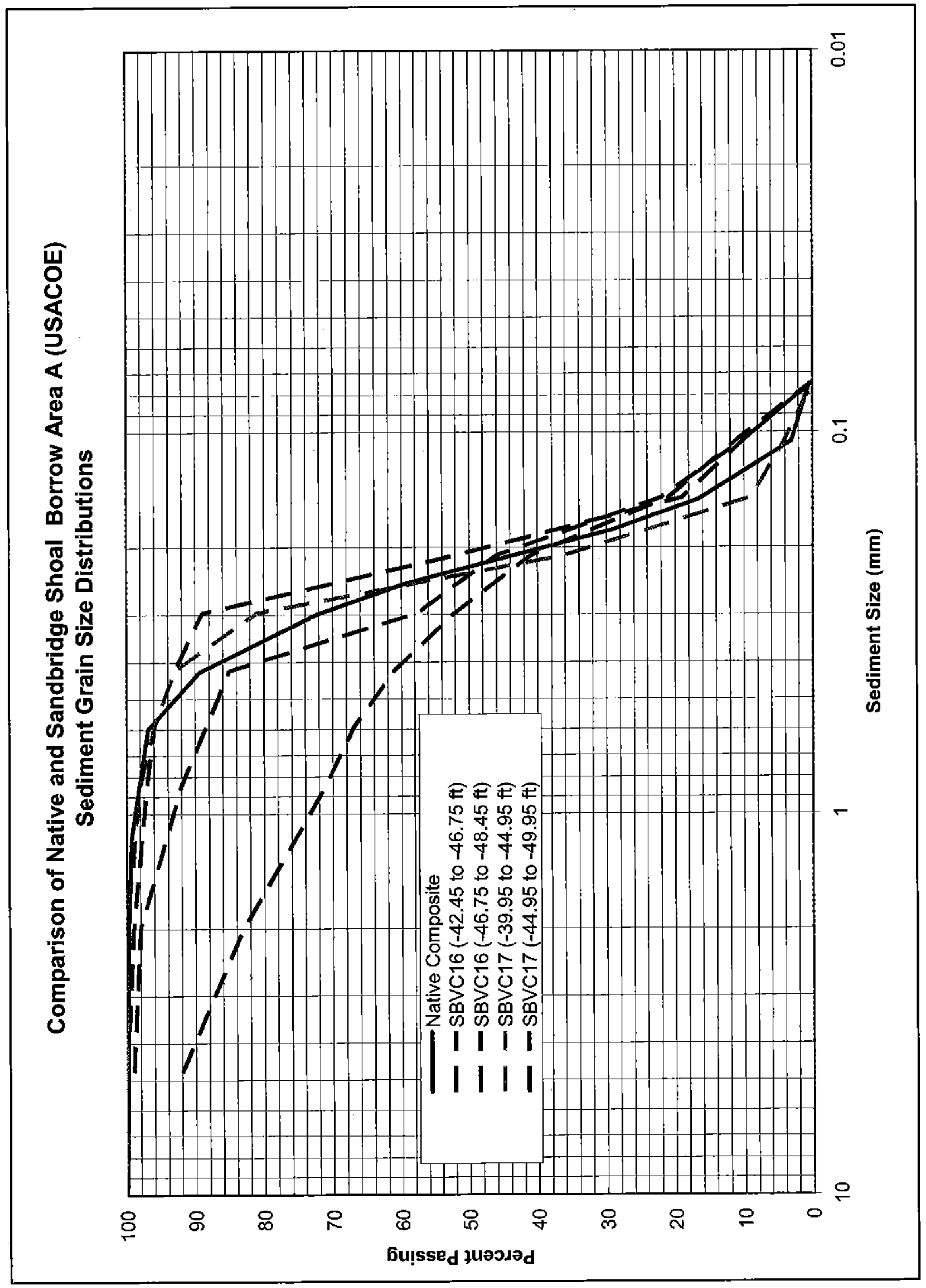

Figure 1-16 Comparison of Native Composite and USACOE Sandbridge Shoal Borrow Area A Sediment Grain Size Distributions

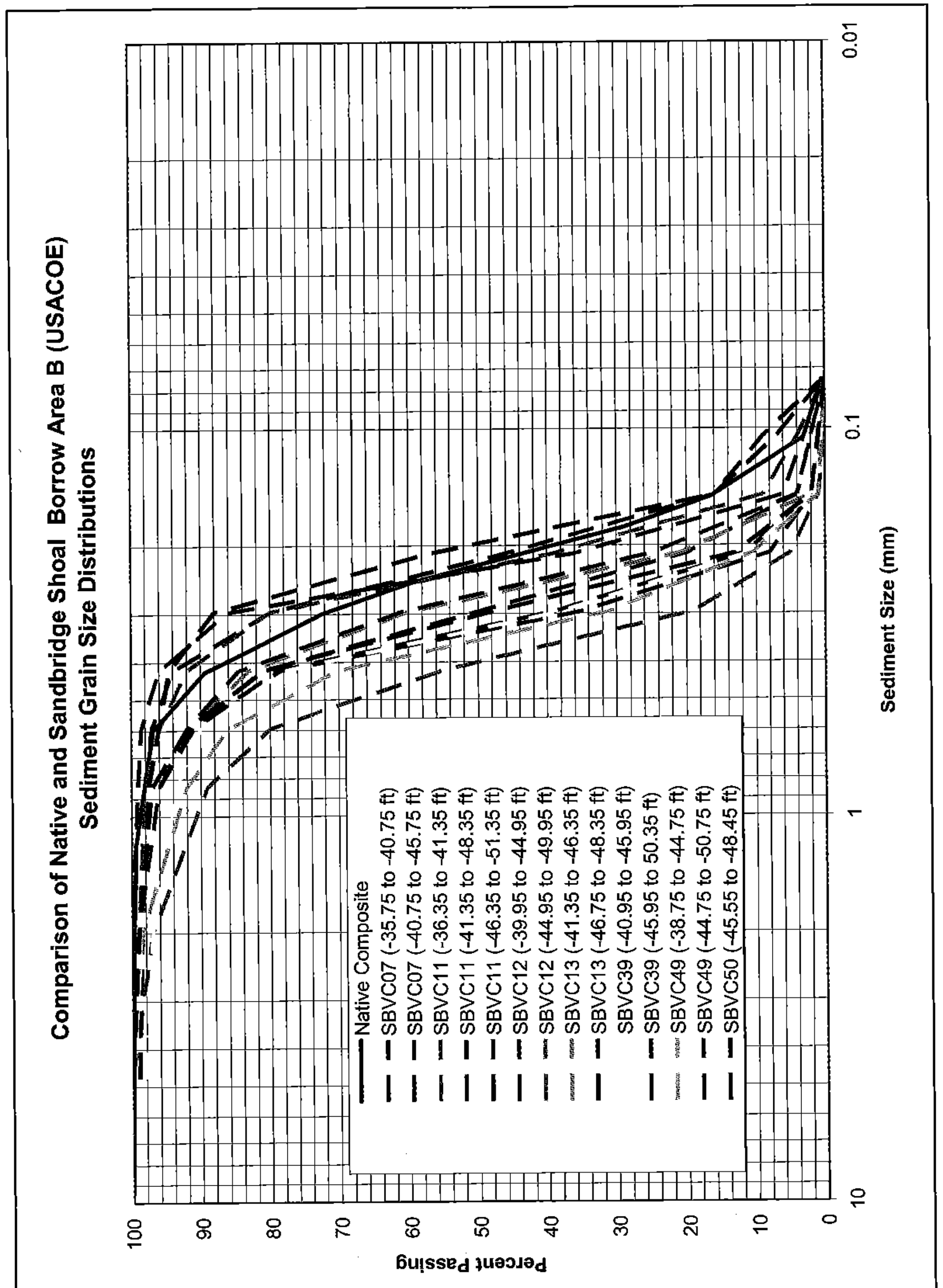

Figure 1-17 Comparison of Native Composite and USACOE Sandbridge Shoal Borrow Area B Sediment Grain Size Distributions

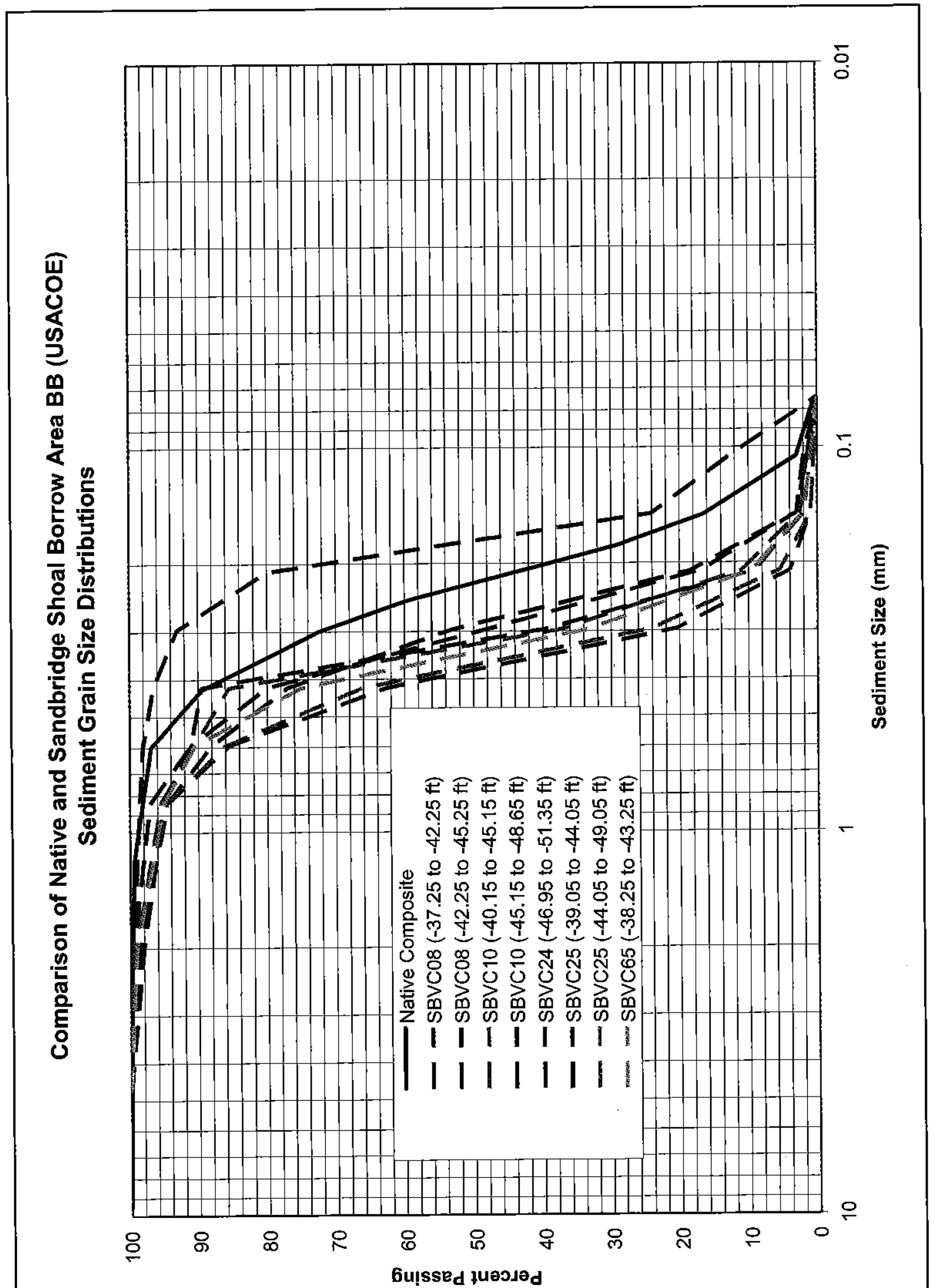

Figure 1-18 Comparison of Native Composite and USACOE Sandbridge Shoal Borrow Area BB Sediment Grain Size Distributions